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February 25, 1993

Dr. Robert Pohanka
Office of Naval Research
Code 1131
800 North Quincy Street
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Dear Dr. Pohanka:

I like to take this opportunity to express our gratitude for your and your agency's support for the HTSC symposium. I had also enjoyed my visit at ONR and the discussion with you and other program mangers there.

Enclosed here is the much delayed report of the symposium. Please feel free to contact me if you need more information. I hope that you will be around New York area and we can invite you here to visit our lab or give us a seminar. I would like to extend my invitation to your colleagues as well.

Thank you again.

Sincerely yours,

Siu-Wai Chan

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encl: report
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CALL FOR PAPERS

1991 Fall Meeting of the Materials Research Society

Symposium on

HIGH-TEMPERATURE SUPERCONDUCTORS: MATERIALS RESEARCH FOR EMERGING TECHNOLOGIES

Boston, Massachusetts -- December 2-6, 1991

This symposium is a sequel to the many previous MRS symposia devoted to the high-T_c superconducting materials. This symposium series provides a special forum for the announcements of new materials and new or improved processing methods for bulk materials and thin films.

The emergence of thin film and bulk technologies has resulted in an increasing emphasis in applications. The purpose of this symposium is to bring together a group of interdisciplinary scientists and engineers to help to identify and solve the material related issues that still hamper the application of HTS materials.

Specific topics to be emphasized include:

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- **Weak links and Josephson junctions: formation and control of properties**
- **Effect of processing on properties of thin films**
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There will be a plenary section that will address the current state of experimental and theoretical understanding of the HTS materials. We plan to have an evening panel discussion that will address outstanding issues for HTS applications.

Abstracts of contributed papers and one or two pages of supporting material (five copies) must be received at MRS Headquarters no later than July 1, 1991.

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Summary Report of The Symposium on
High Temperature Superconductors:
Materials Research for Emerging Technologies
Held at MRS 1991 Fall Meeting at Boston

The first few sessions of the 1991 Materials Research Society symposium on high temperature superconductivity focussed on the basic physics and physical characterization of materials, and on new materials. In spite of the increasing difficulty in finding new superconducting oxides, the MRS remains an important forum for their description and discussion. The very large poster session on the evening of the second day (75 posters), concentrating on the area of superconducting materials and their physical properties, was a good reflection of the ongoing vitality of the field.

The sessions opened with review talks by three distinguished workers in the field, B. Batlogg (AT&T) summarizing the basic physics of high T_c materials, A.W. Sleight (Oregon State University) summarizing the basic chemistry of high T_c materials, and J.R. Clem (Ames Laboratory) summarizing the state of understanding of flux flow dynamics of high T_c materials. To briefly summarize their general observations: Batlogg noted that there are many properties of the carriers in the normal state that suggest that the carriers in copper oxides are indeed special and unique charge liquids; Sleight focussed on the fact that the superconducting copper oxides all appear to be metastable materials and in fact are structurally defective; Clem argued that the magnetic vortex dynamics in cuprates were made complex (and interesting) due to their-two dimensional structures and their 2d to 3d crossover was an important aspect to consider in interpretation of experimental observations.

The contributed sessions included many interesting talks -- too many to do individual justice to in a brief summary. A few of the highlights will be described in the following paragraphs.

J.R. Tobin (Lawrence Livermore) and R. Liu (Argonne National Laboratory) discussed angle resolved photoemission work. They generally find that the observed bands crossing the fermi level are in good agreement with band structure calculations. Experiments on untwinned and oxygen deficient $Ba_2YCu_3O_7$ are contributing a great deal to the interpretation of the spectral features. C. Lieber (Harvard University) described experiments performed by STM and HREELS probing the electronic state of $Bi_2Sr_2CaCu_2O_8$ single crystals; the results were interpreted as showing that the energy gap in BSCCO is large, $2\Delta/KT_c \sim 8$, and has a non BCS temperature dependence.

A dozen or so talks were presented on new materials. D.C. Johnston (Ames Laboratory) described a surprising new series of highly

oxygen deficient phases based on Ln_2CuO_4 prepared by a novel and innovative synthetic route. He also described work on $La_{1-x}Sr_xVO_3$, a material which in its metallic state shows indications of being in a strongly correlated electronic state. M. Takano (Kyoto University) described the synthesis of new, very high temperature (110K) copper oxide superconductors based on the "all layer phase", $(Sr,Ca)CuO_2$. These materials are very exciting from the basic science point of view, but, as they must be prepared at very high pressures and temperatures (6GPa,1000°C), are not likely to be easily prepared in commercially important quantities. Also working at very high total pressures, M. Smith (University of Texas, Austin) described the new <u>electron doped</u> superconductor $Sr_{1-x}Nd_xCuO_2$. This material is of considerable scientific interest as being only the second known electron doped copper oxide superconductor. Its T_c is 40K. J. Karpinski (ETH, Zurich) described the P_{O_2}-temperature-composition phase equilibria in the important Ba-Y-Cu-O chemical system at oxygen pressures between 1 and 3000 atmospheres and temperatures up to 1000°C. Finally, A. Hebard (AT&T) presented a review talk on the exciting new class of superconductors based on alkali doped C_{60}. The T_c's for the best materials are higher than 30K. Like copper oxides, these materials have short superconducting coherence lengths. These materials are now being studied by many groups. Their goals are to increase T_c's and solve the problem of spontaneous combustion for these materials.

Starting from Tuesday afternoon, the symposium was concentrated on thin films and devices of HTSC materials. There were many interesting talks -- again too many to do individual justice to in a brief summary. A few of the highlights will be described in the following paragraphs.

David Fenner from Advanced Fuel Research reported on infrared response of epitaxial YBCO films on silicon. Their data demonstrated a highly sensitive bolometer on Si. A photo response curve is shown in Fig.1.

Eom from AT&T talked about the different 90-degree boundaries of YBCO films and their critical current behaviors which stemmed from, complemented and confirmed previous results shown by Siu-Wai Chan and the later S. Badcock's results on the 90 degree boundaries.

Lee from Conductus reported on the use of 45-degree boundaries as weak-links in squid applications. Their 15-layer integrated circuit with pick-up coil showed reasonable performance of a squid at 77K. They also have a product announcement at the meeting (see Fig. 2).

C. Platt from Univ. of IL showed very BCS-like tunneling data of BKBO bismuthate. Their tunneling junctions taking advantage of longer coherence length were made from 2 thin films of BKBO bismuthate sandwiching a thin insulating films, which made their results so much more reproducible than other tunneling data of

oxide superconductors.

The last two days of the symposium were focused on the critical current issue of the HTSC materials. There were many participants particular there was large presence of the overseas researchers coming for just the last two days of the symposium. Some of the highlight are summarized in the following paragraphs.

Matsui from NIRIM Tsukuba, Japan reported on the different electron damages of superconducting cuprates. He directly observed the decomposition of double chains in YBCO into CuO and single chain YBCO. i.e. 248-> CuO + 123. The following table summarize his results.

Materials	electron energy	200-400Kev	800-1300Kev
Bi,Pb cuprates		A	A
Y-2-3		D	A
Nd Ce Cuprates		D	D

where D stands for decomposition and A stands for amorphous transformation. Interestingly, he has observed the amorphous transformation always starts at the double chain regions.

L. Civale reported on the columnar defects induced by heavy ion implantation to 123 materials. These elongated defects are much more effective as flux pinning centers than the point defects. Sn^{+} at a fluency of $1.5x10^{11}$ was used for 21 micron thick crystals.

Zhao from Univ. of Houston reported on their novel method of using Li doped 123 + thermal neutrons inducing internal nuclear reaction for uniform radiation induced flux-pinning defects..

Tiefel and Jin from AT&T were trying to settle the controversy of the true effect of 211 on Jc. Previously, McGinn reported 211 reduced Jc while Murakami stated that 211 greatly improved Jc. Later, Salama's group raised the issue of the methods of introducing 211 in the materials can be the true issue. This is still unsettled.

On friday afternon, there were more than 200 people attending the last session. This was quite a spectacular sight for the last two sessions on Friday. There many interesing talks and we are not really doing justice here. Some of the hightlights are summarized in the following paragraphs.

Babcock from Wisconsin reported that a sigma 29 boundary does have a 1nm-2nm thick amorphous CuO layer which give a resistive behavior at low temperature.

Chan from Columbia U. drawing from her previous results of special boundaries e.g. sigma 3, sigma 5 sigma 13 boundaries in YBCO films grwon on (001), (014) SrTiO3 and (001) MgO as well as the Conductus's results on 45 degree boundaries stated that clean boundaries are necessary but not sufficient condition for good Jc transport across boundaries.

J. Ekin from NIST Colorado reported on the effect of uniaxial compressive stress on the critical temperature of 123 single crystals and films.

Sato from Sumitomo Electric, Osaka, Japan reported on their Jc of their Bi2223 tape of having $2x10^4$ A/cm_2 at 4.2K and 23T. (see the attached paper).

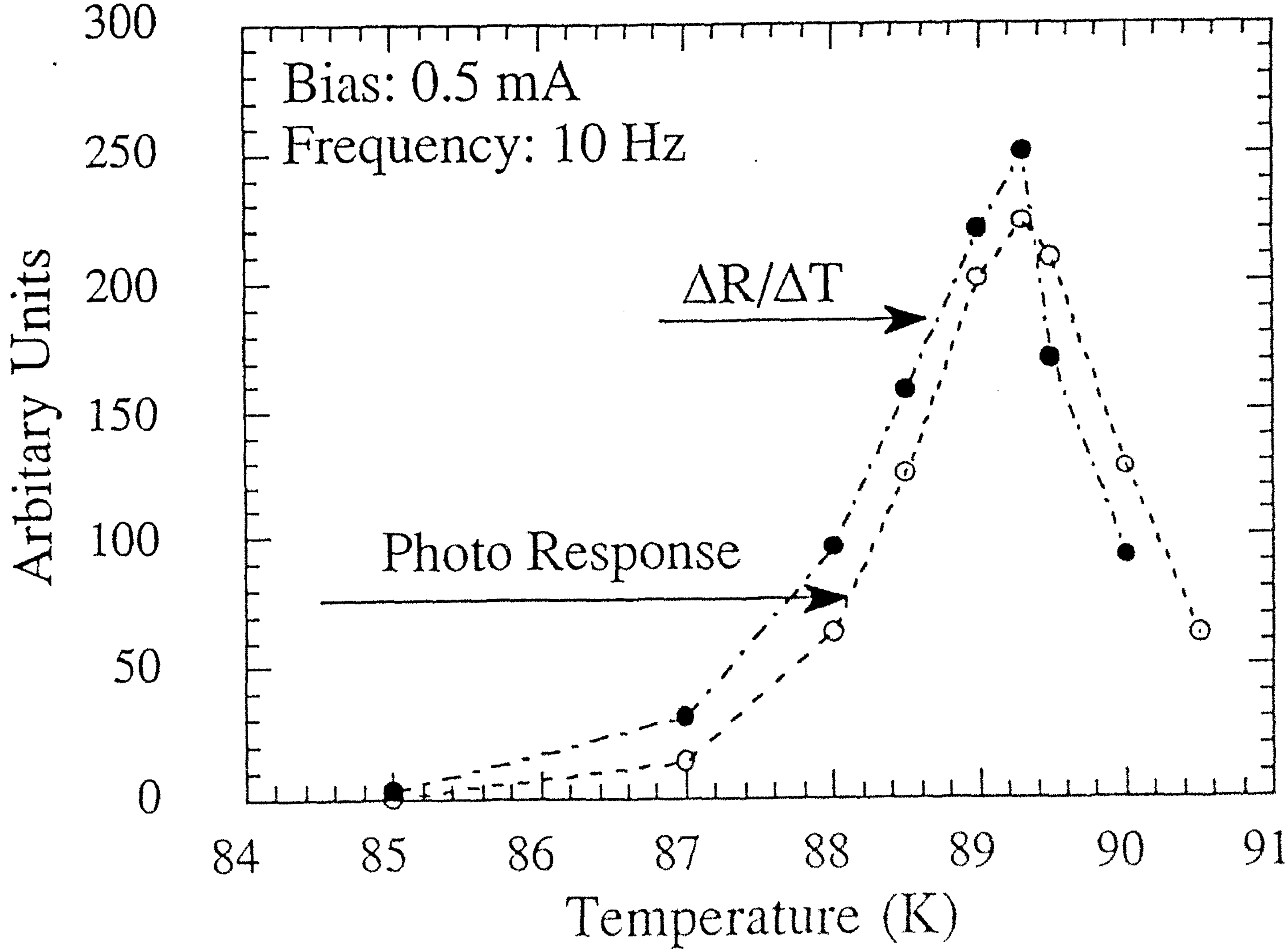
The U. of Houston group also had a great presence in reporting their processing and Jc valves.

At the end of the last talk, there were still 250 people in the room. I must admit that I have never seen such an enthusiastic crowd for a Friday afternoon session.

The grouping of the bulk Jc talks to the last 2 days had worked out well. Overall the symposium was extremely successful and there were many exchanges of scientific and technical ideas through out the five-day symposium.

Fig. 1

YBCO Bolometer on YSZ/Si



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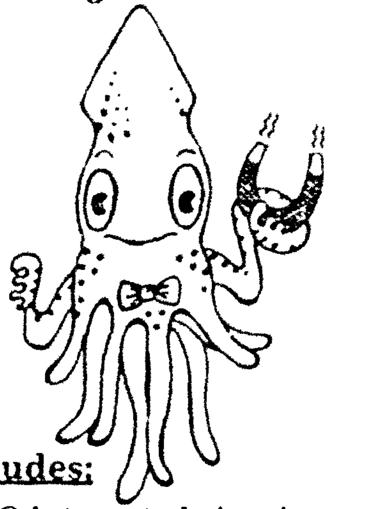

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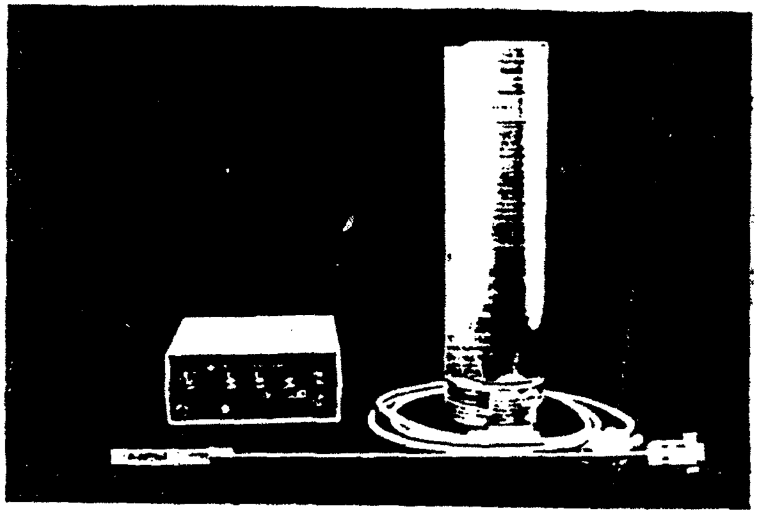

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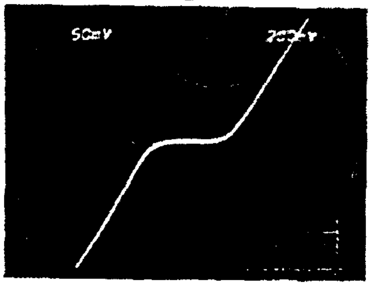

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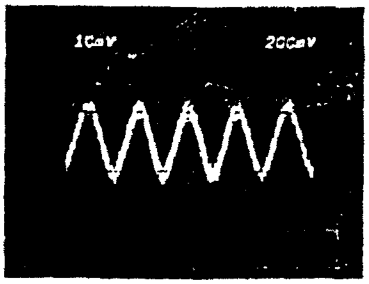

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Transport Critical Current Properties of Silver-Sheathed Bi-Based Superconducting Tapes and Coils at 4.2 K

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Transport critical current properties of silver-sheathed bismuth-based superconducting tapes and coils were investigated at 4.2 K and up to 25 T. Critical currents showed isotropic properties when the direction of the applied magnetic field changed from parallel to the tape surface to perpendicular, i.e., J_c of 8.9×10^4 A/cm^2 for $H /\!/$ tape and 6.6×10^4 A/cm^2 for $H \perp$ tape at 23 T. Critical current properties of a three double-pancake coil were consistent with those of short specimens, showing little change at from 5 to 23 T.

KEYWORDS: critical currents, (Bi, Pb)-Sr-Ca-Cu-O, tapes, coils

Since the first report of superconductivity in the Bi-Sr-Ca-Cu-O system by Maeda *et al.*,[1] many studies of critical current density have been done from the point of view of applications in liquid nitrogen. Recently, we reported[2] that the combination of bismuth high-T_c phase[3] and the powder-in-tube technique produced a tape having J_c of 5.4×10^4 A/cm^2 at 77.3 K in a zero magnetic field. Apart from applications at liquid-nitrogen temperature, a super high-field magnet application of these tapes at a temperature range from 4.2 K to 20 K is one of the most promising uses.[4,5]

In this paper, we describe the magnetic field direction dependence of critical currents of silver-sheathed bismuth (high-T_c phase) superconducting tapes at 4.2 K and up to 25 T, and also critical current properties of coils at 4.2 K and up to 23 T.

Appropriate amounts of Bi, Pb, Sr, Ca and Cu oxides and carbonates with 4N to 5N purity were mixed, sintered and ground, as described in the previous paper.[6] The ground powder was put into silver tubes, drawn into round wires and then made into tapes by pressing or rolling. The nominal cation ratio was Bi:Pb:Sr:Ca:Cu = 1.8:0.4:2.0:2.2:3.0. These wires were sintered twice and made into high-J_c superconducting tapes. The typical size of these tapes was 0.15 mm thick and 4 mm wide. The critical temperature of these tapes was 106 K. The magnetic field dependence of critical currents of these tapes at 4.2 K was evaluated using the hybrid magnet in the High Field Laboratory for Superconducting Materials at Tohoku University with the 4-probe dc method. A three-double-pancake coil was made with the bundle conductor technique,[7] four tapes in parallel winding in this case, and also evaluated in the same manner as the tapes.

Figure 1 shows the magnetic field direction dependence of critical current density of the tapes at 4.2 K and up to 25 T. J_c at 23 T was 8.9×10^4 A/cm^2 for the applied field parallel to the tape surface and 6.6×10^4 A/cm^2 for the perpendicular one. The anisotropy factor, $J_c(H\perp)/J_c(H/\!/)$, was 0.74 at 23 T. The anisotropy factors at from 5 to 23 T are summarized in Fig. 2. Further-

plied field directions, parallel and perpendicular to the tape surface, the behavior of critical current density was very similar. Little change of critical current density was

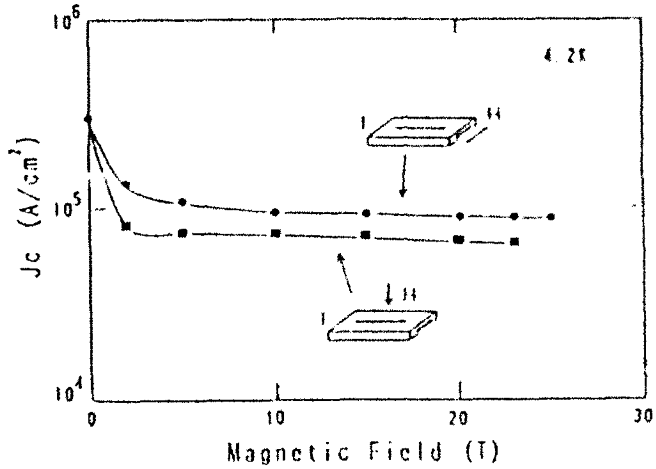

Fig. 1. Magnetic field direction dependence of critical current density of silver-sheathed bismuth (high-T_c phase) superconducting tapes at 4.2 K and up to 25 T.

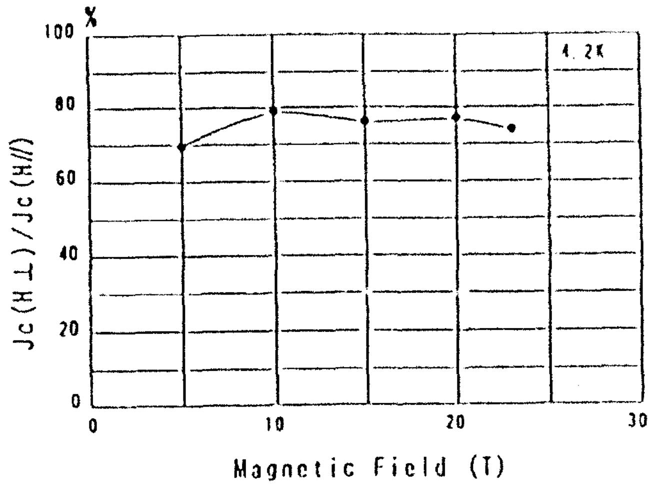

Fig. 2. Anisotropy factor of critical current density at 4.2 K and up to

observed at from 5 to 23 or 25 T for both directions of the applied magnetic field.

In these tapes, fine dispersions of nonsuperconducting phases, such as Ca_2PbO_4 and (Ca, Sr)-Cu-O, were observed as the critical current density improved.[7] It is possible that these finely dispersed nonsuperconducting phases work with invisible pointlike defects to show strong pinning characteristics, as shown in Fig. 1.

For building a super high-field magnet, it is necessary to suppress the mechanical damage to the superconducting tape due to the large electromagnetic force. One example of this effect was shown previously.[8] The previous data showed that the critical current of the three-double-pancake coil at 23 T was half of the value at 5 T. In the case of the short tape sample, the change of critical current from 5 to 23 T was around 20%. This degradation was considered to be attributable to the high stress, 2,000 kg/cm^2 at 23 T. In considering these results, an improved technique was chosen, including epoxy resin impregnation and a stainless-steel jacket. In particular, epoxy resin impregnation was performed to fill in the winding layers. Table I shows the parameters of a three-double-pancake coil. Critical current density of this coil at 77.3 K was 4,400 A/cm^2, showing a similar value to that of the previous coil, 3,900 A/cm^2. Critical current properties of each double-pancake coil were measured at 4.2 K and up to 23 T. Each coil showed similar properties in liquid nitrogen without a back-up field, but in liquid helium with a high back-up field, the central coil showed the lowest critical current. Critical current density of this central coil is shown in Fig. 3 with the previous data.[8] The change of critical current from 5 to 23 T was 76% in this case, showing a result similar to those of the short tape sample. The critical current of this three-double-pancake coil was 95 A at 23 T external field, and the maximum magnetic field of the coil was 23.314 T. Because the dimensions and the fabricating procedure were the same for the present three-double-pancake coil and the previous one, the result showed the effectiveness of anti-stress improvements.

In summary, critical current properties of silver-sheathed bismuth (high-T_c phase) superconducting tapes and coils were evaluated at 4.2 K. The magnetic field direction dependence of critical current was relatively isotropic. It was possible to achieve the expected characteristics of the tape for super high-field magnets.

The authors greatly appreciate Prof. K. Watanabe, HFLSM of Tohoku University, for measuring the properties using a hybrid magnet, and Prof. Y. Iwasa, FBNML of MIT, for useful discussion.

Table I. Parameters of a three double pancake coil

Item	Parameter	
Wire	Thickness (mm)	0.56 (0.14 × 4)
	Width (mm)	3.7
	Inner diameter (mm)	8.5
Coil	Outer diameter (mm)	35
	Turn	84 (14 turn × 2 × 3)

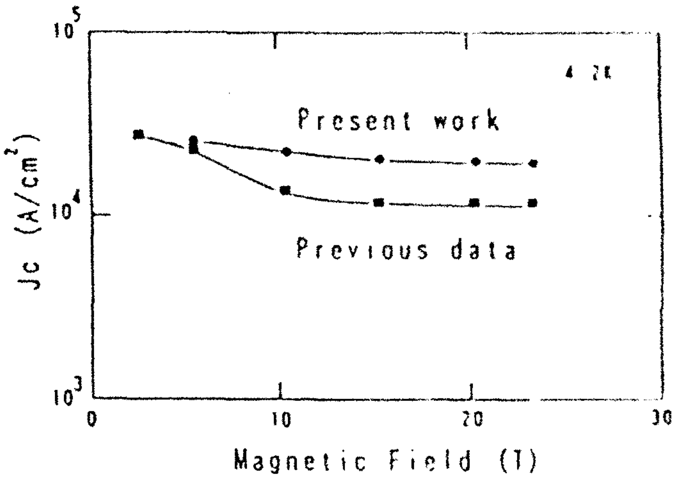

Fig. 3. Critical current density of a three-double-pancake coil at 4.2 K and external field up to 23 T.

References

1) H. Maeda, Y. Tanaka, M. Fukutomi and T. Asano: Jpn. J. Appl. Phys. 27 (1988) L209.
2) M. Ueyama, T. Hikata, K. Kato and K. Sato: Jpn. J. Appl. Phys. 30 (1991) L1384.
3) M. Takano, J. Takada, K. Oda, H. Kitaguchi, Y. Miura, Y. Ikeda, Y. Tomii and H. Mazaki: Jpn. J. Appl. Phys. 27 (1988) L1041.
4) Y. Iwasa and Y. M. Butt: Cryogenics 30 (1990) 37.
5) K. Sato, T. Hikata and Y. Iwasa: Appl. Phys. Lett. 57 (1990) 1928.
6) T. Hikata, T. Nishikawa, H. Mukai, K. Sato and H. Hitotsuyanagi: Jpn. J. Appl. Phys. 28 (1989) L1204.
7) H. Mukai, N. Shibuta, T. Masuda, T. Hikata, M. Ueyama, T. Kato and K. Sato: *Proc. 3rd Int. Symp. Superconductivity, Sendai, 1990* (Springer, Tokyo, 1991) p. 607.
8) K. Sato, N. Shibuta, H. Mukai, T. Hikata, M. Ueyama and T. Kato: to be published in J. Appl. Phys. 70 (1991).